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H2H
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(54) Direct current power supply

(57) A direct current power supply includes a power transformer (T) of which a secondary winding has a plurality of output terminals (H, L and G). Rectifiers (D1-D5) are connected to the output terminals. An input voltage-detecting circuit (3) detects the input alternating current voltage and operates a switch (Tr4), opening and closing a line (6) of the rectifying circuit systems to select and connect groups of rectifiers forming rectifying circuits to smoothing capacitors (C1, C2). Depending on the amplitude of the input voltage, the output terminals of the secondary winding of the power supply transformer and the rectifying circuits are switched automatically to reduce variation in the direct current voltage supplied to a series regulator circuit (4).

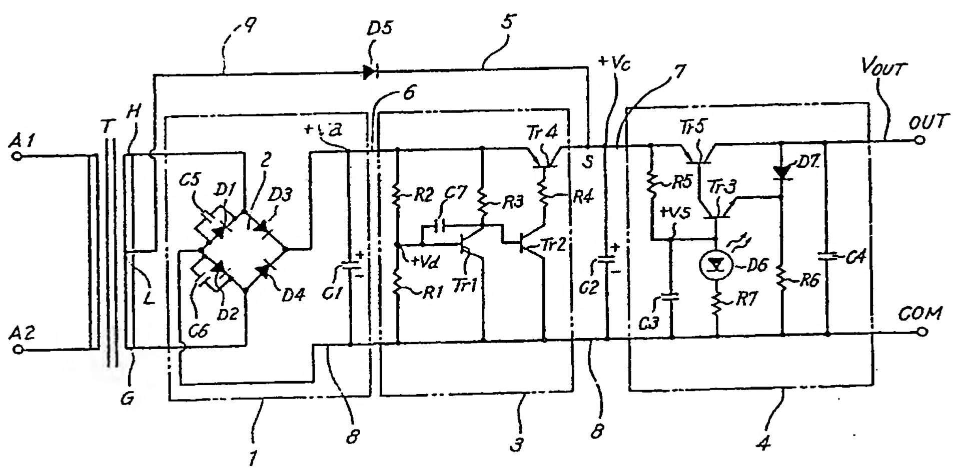

FIG 1

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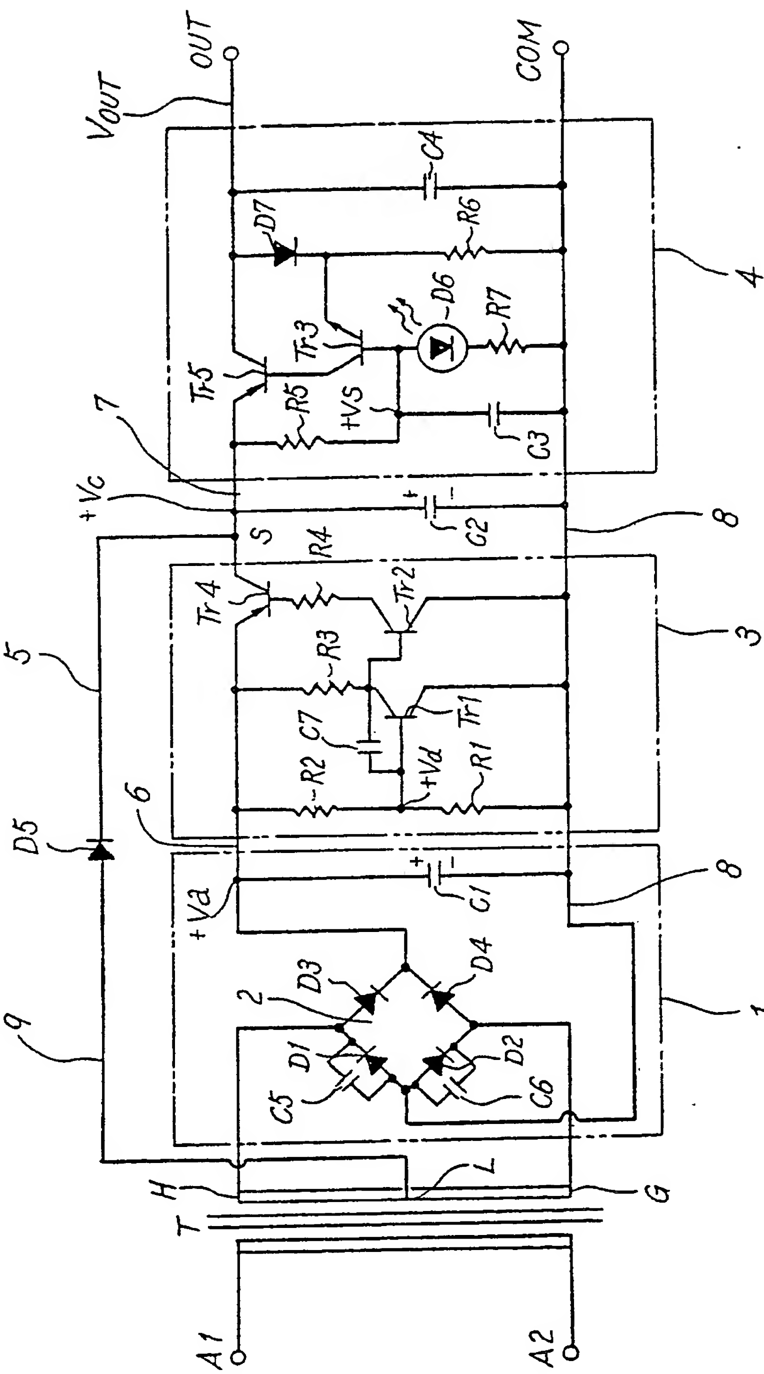


FIG 1

FIG 2 (a)

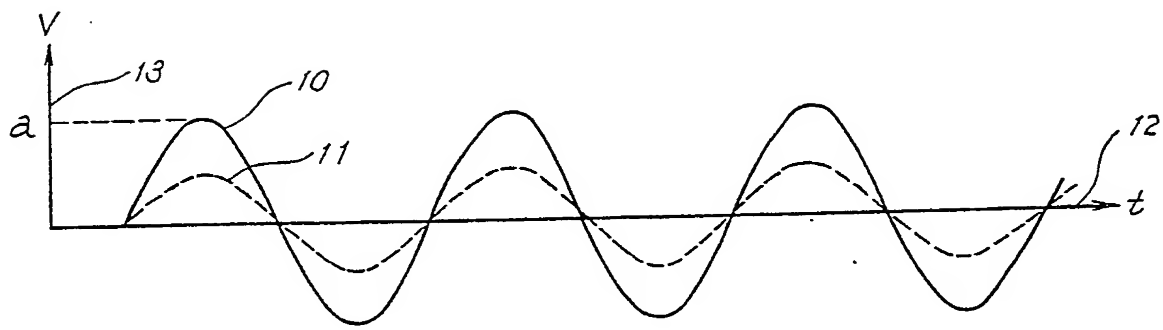
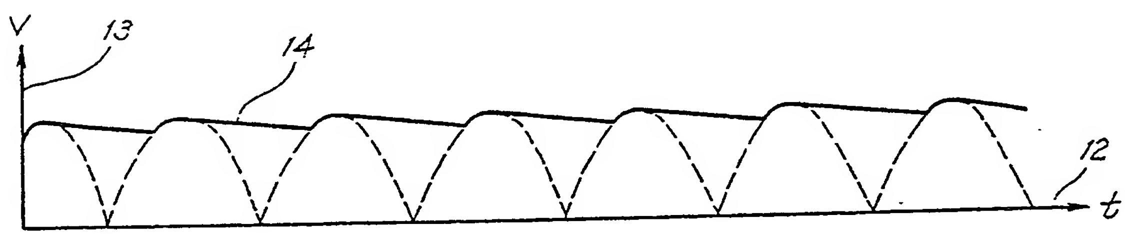


FIG 2 (b)



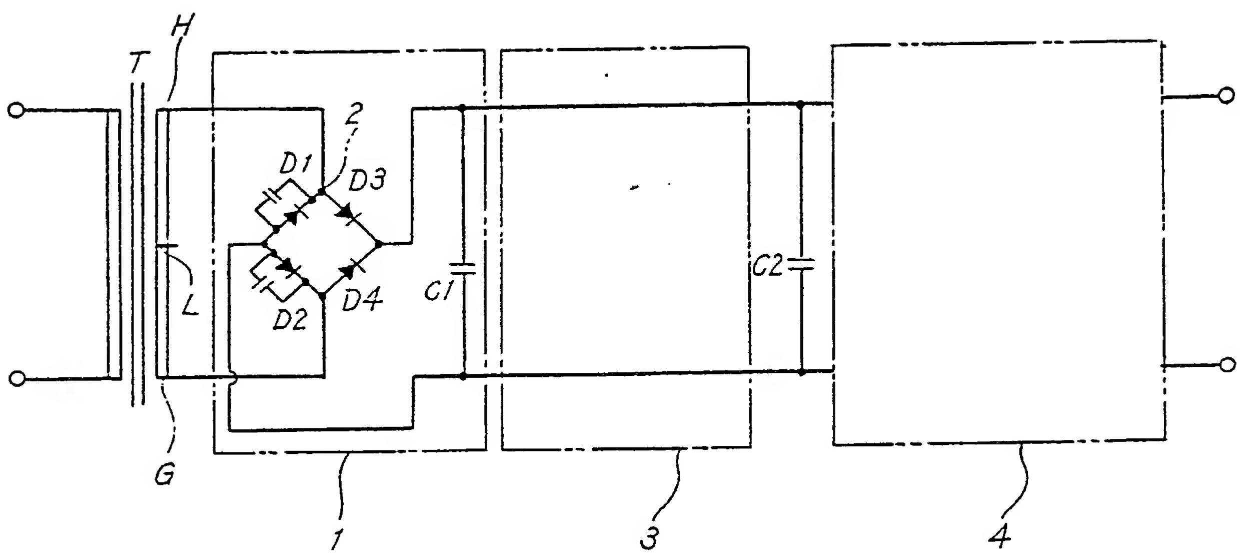


FIG 3

FIG 4 (a)

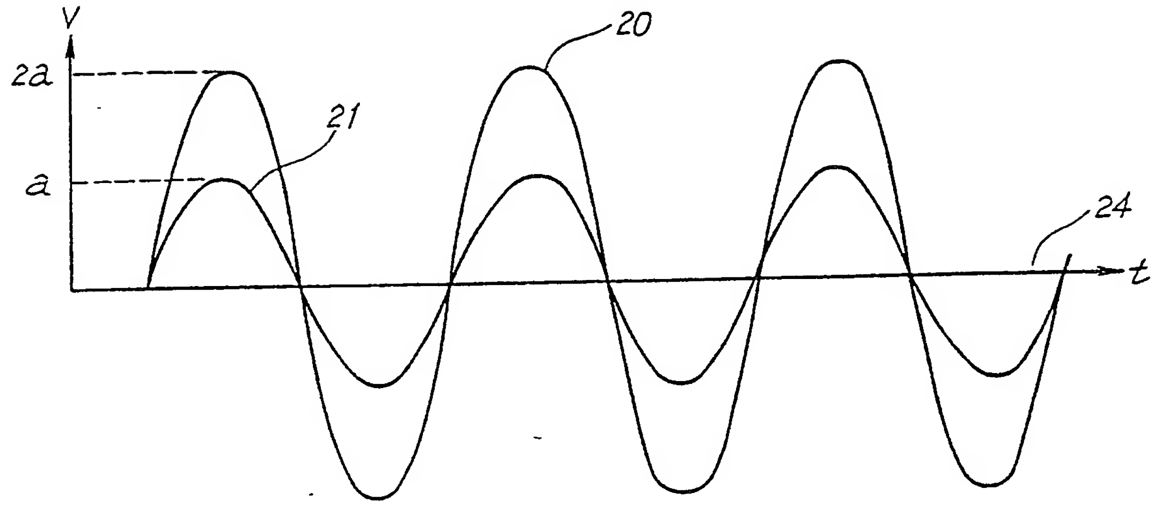


FIG 4 (b)

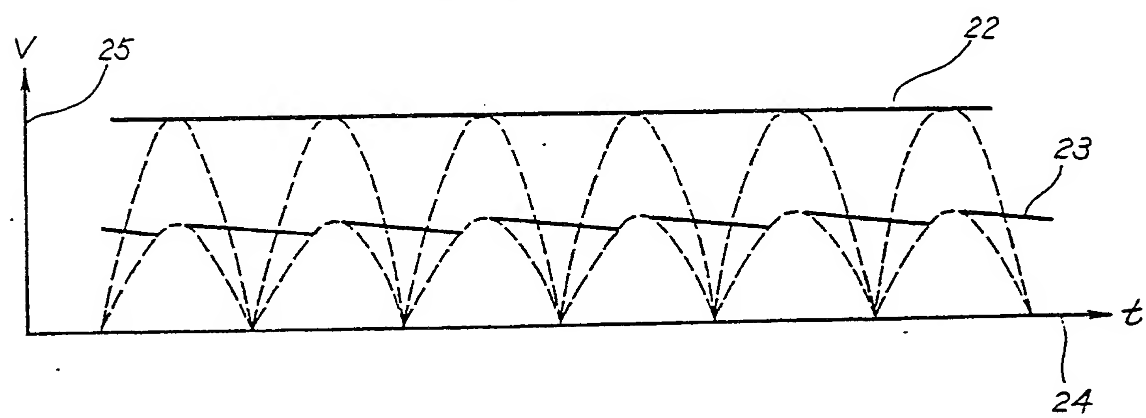


FIG 5 (a)

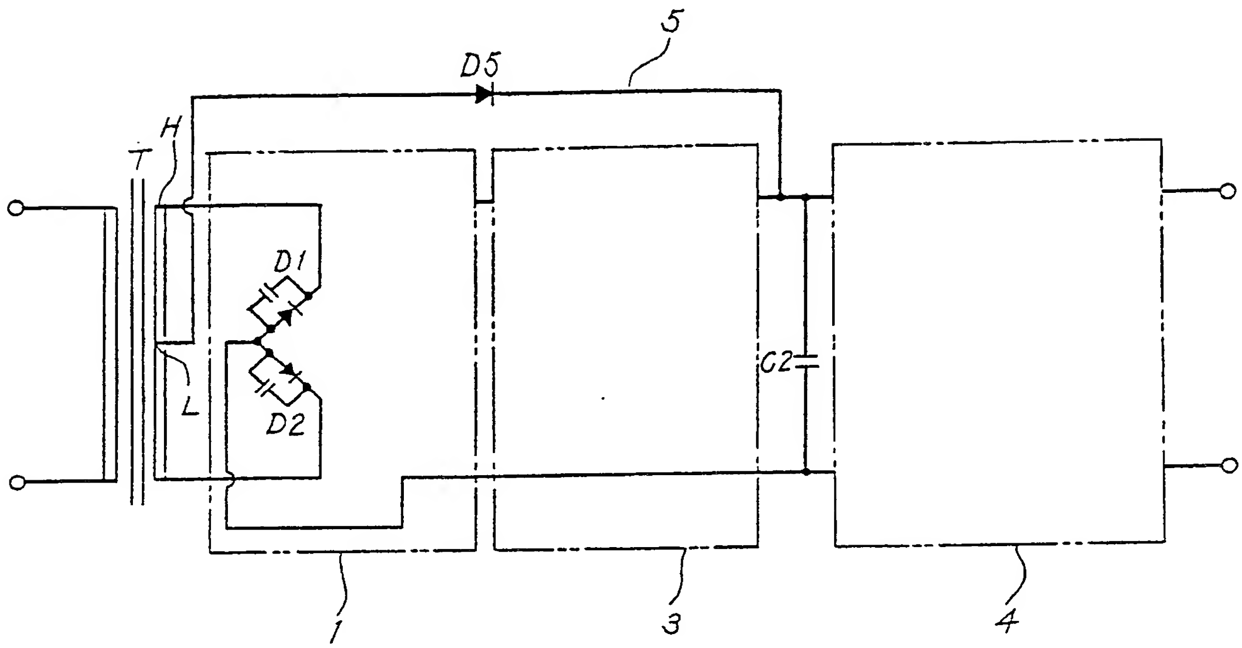
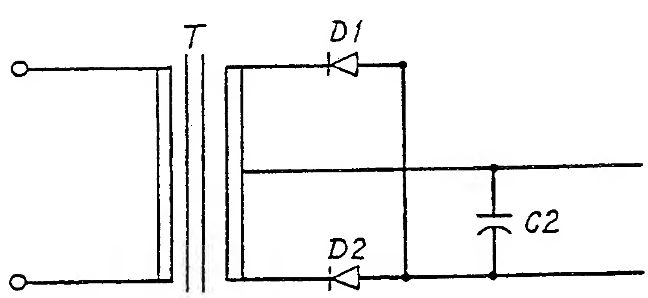


FIG 5 (b)



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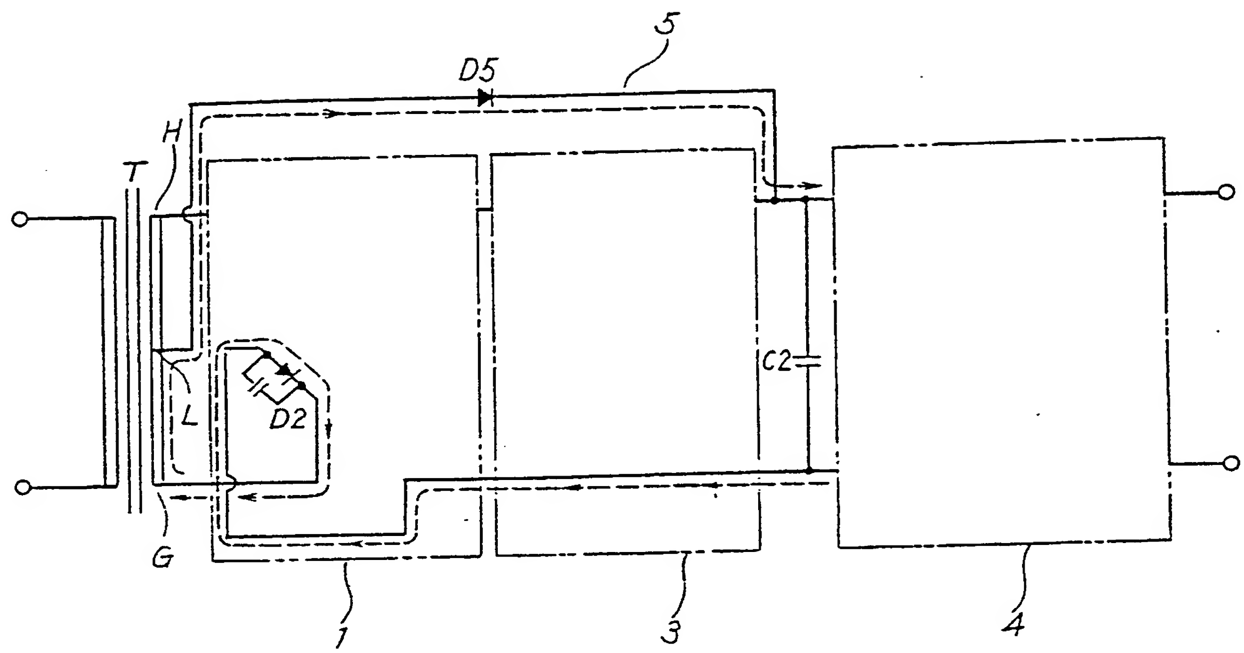

FIG 6

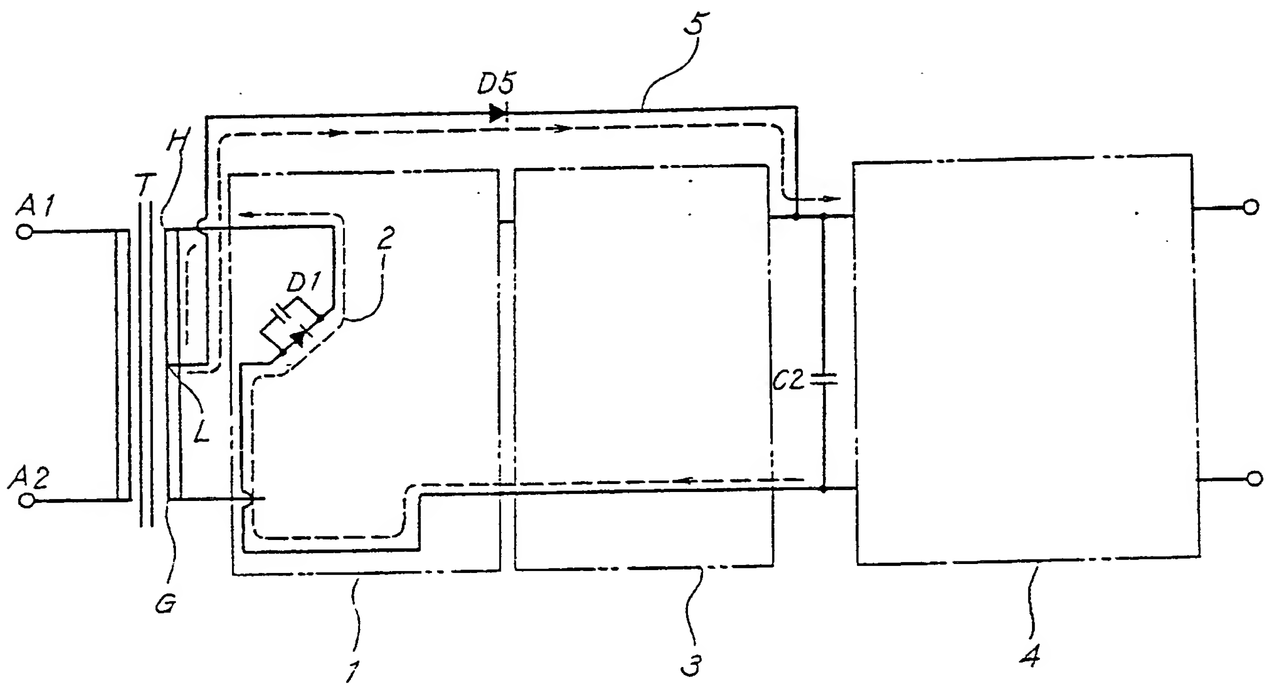

FIG 7

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DIRECT CURRENT POWER SUPPLY

This invention relates to a direct current power supply deriving a direct current output from an alternating current input and more particularly to a direct current power supply converting alternating current to direct current and connectable directly to domestic mains supplies with various rated voltages.

Hitherto an efficient power supply able to cope with the various mains voltages and fluctuations in countries of the world has not yet been realized. Countries use domestic power systems with various rated voltages in accordance with backgrounds of their histories, societies and economies. For example, the rated voltage of a household supply is frequently selected at the range of 100V-120V for a nominal 100V-system or 200V-240V for a nominal 200V-system. In addition, the domestic power supply system in a single country possibly uses a mixture of the 100V and 200V systems. A direct current power supply for electronic devices is required which can flexibly cope with various input voltages.

A switching type power supply is known which can cope with two kinds of high and low voltages. Such a power supply directly rectifies a commercial alternating current into direct current, without a power transformer, and then converts the direct current into a high-frequency alternating current through an inverter. The voltage of the high-frequency alternating current is then reduced to a desired value through a high-frequency transformer,

whose input is rectified and smoothed to provide the required DC output. A power transistor usually regulates the voltage of the direct current output by means of pulse width modulation.

A switching power supply can readily cope with wide variations of the alternating current input voltage and shows a high efficiency and the switching regulator system can handle various voltages. However, such power supplies are expensive and the switching action causes noise which includes not only a switching-frequency component but also wide band noise components extending into high-frequency and radio frequency bands. Therefore, the switching regulator system causes problems on devices which tend to be affected by noise e.g. radio receivers and the like.

A direct current power supply using a voltage-reducing power transformer, a rectifying-and-smoothing circuit and a series regulator is also known which is able to cope with different input voltages. Such a series-regulator-type direct current power supply steps down the voltage of the domestic power source to a desired value through the power transformer and then rectifies the resulting current into a direct current. The output voltage of the resulting direct current is stabilized by the voltage drop between the collector and emitter of a power transistor in a main line so that no switching noise is produced. However, this system necessarily produces a power loss constituting a product of the voltage drop between the collector and emitter of the power transistor

and the load current. The voltage drop across the power transistor and hence the power loss increases as the input voltage increases and heat dissipation becomes a problem. The series regulator power supply cannot handle wide variations of the alternating current input voltage in principle and where necessary the primary winding of the power transformer may have a plurality of taps and a manual selector switch. A corresponding selection is then carried out in response to the prevailing rated voltage of the domestic power source.

A general object of the invention is to provide an improved form of power supply.

A further object of the invention is to provide a series-regulator-type direct current power supply which will not produce switching noise and is small, lightweight and economical and does not require the manual operation of a selector switch to cope with a change in input voltage.

According to the invention there is provided a direct current power supply for converting alternating current into direct current comprising: a power transformer having a primary winding connectible to a source of alternating current and a secondary winding with a plurality of outputs; a plurality of rectifying means connected to the outputs of the transformer; detecting means for detecting a predetermined level of alternating current voltage; and switching means for connecting and disconnecting the rectifying means under control of the detecting means;

whereby an appropriate rectifying circuit is selected from the rectifying means in response to a variation of the amplitude of the alternating current voltage to prevent variation in output voltage.

In a preferred design, one of the outputs of the secondary winding of the power transformer and a group of rectifying means connected to the output collectively form a single-phase bridge rectifying circuit which is operative when the input alternating current voltage is low and another ot the outputs of the secondary winding of the power transformer and a group of rectifying means connected to the ouput collectively form a single-phase full-wave-rectifying circuit which is operative when the input alternating current voltage is high. Smoothing capacitors can be connected with the rectifying circuits and a regulator circuit can be adopted in the output stage of the power supply.

In another aspect the invention provides a direct current power supply comprising a power transformer having a primary winding with input terminals for connection to a source of alternating current and a secondary winding with output terminals, a plurality of rectifying circuits connected to the output terminals and means for automatically selecting an appropriate rectifying circuit in dependence on the voltage applied to the input terminals.

The invention may be understood more readily and various other aspects and features of the invention may

become apparent from consideration of the following description.

An embodiment of the invention will now be described by way of example only, with reference to the accompanying drawings wherein:-

Fig. 1 is a circuit diagram representing a power supply constructed in accordance with the invention;

Fig. 2(a) and Fig. 2(b) are waveform diagrams illustrating the operation of the power supply when an input voltage is taken from a 100V-source;

Fig. 3 illustrates the rectifying circuit and operation of the supply when the input voltage is taken from the 100V-source;

Fig. 4(a) and Fig. 4(b) are waveform diagrams illustrating the operation of the power supply when the input voltage is taken from a 200V-source;

Fig. 5(a) and Fig. 5(b) illustrate the rectifying circuit and operation of the supply when the input voltage is taken from the 200V-source; and

Figs. 6 and 7 are diagrams illustrating the directions of current in a charging loop when the input voltage is taken from the 200V-source.

Fig. 1 illustrates a direct current power supply representing one embodiment of the invention. In Fig. 1, a rectifying and smoothing circuit is indicated at 1, a diode bridge circuit is indicated at 2, a voltage detector is indicated at 3 and a voltage regulator/stabilizer is indicated at 4. A line connected to a diode D5 is

indicated at 5. An output line of the rectifying and smoothing circuit 1 is indicated at 6. An output line of a main smoothing capacitor C2 is indicated at 7. A common line is indicated at 8. Primary-winding-side or input terminals of a power transformer which reduces voltage are indicated at A1 and A2. Two output terminals across a secondary winding are indicated at H and G. A tap of the secondary winding is indicated at L. Diodes or rectifiers are indicated at D1, D2, D3, D4 and D5. A voltage regulated diode is indicated at D6 and a further diode is indicated at D7. A zener diode is indicated at D6. Respective transistors are indicated at Tr1, Tr2 and Tr3. A switching transistor is indicated at Tr4. An ouput control transistor is indicated at Tr5. An auxiliary smoothing capacitor for detecting an input voltage is indicated at C1 and another capacitor is indicated at C3. Respecting noise-damping capacitors are indicated at C5, C6 and C7. An output voltage of the rectifying and smoothing circuit 1 is indicated at +Va. A charging voltage of the main smoothing capacitor C2 is indicated at +Vc. Resistors are indicated at R1 to R7 and a voltage across the resistor R1 is indicated at +Vd. A base voltage of transistor Tr3 is indicated at +Vs. An output voltage is indicated at V_{OUT} and an output smoothing capacitor is indicated at C4. An output terminal is indicated at OUT. An output terminal of the common line is indicated at COM.

The arrangement of the direct current power supply of

this invention will be described hereinafter with reference to Fig. 1. A primary or input voltage of alternating current is applied to the primary input terminals A1 and A2 of the power transformer T and reduced by the secondary winding to a desired value of voltage. The terminals H and G across the secondary winding are connected to an alternating current input side of the single-phase bridge rectifier circuit 2 comprising the diodes D1, D2, D3, and D4. A rectified output of the single-phase bridge rectifier 2 is smoothed through the auxiliary smoothing capacitor C1 for detecting the input voltage and applied through the output line 6 to the voltage detector 3 as the output voltage +Va. The voltage detector 3 comprises the input voltage detecting circuit and the switching circuit operating in response to the action of the input voltage detecting circuit. The output voltage +Va of the rectifying and smoothing circuit 1 is divided through the resistors R1 and R2, resulting in the voltage +Vd across the resistor R1. One terminal of the resistor R1 is connected to the base of the NPN transistor Tr1 and the other is connected to both the emitter of the transistor Tr1 and the common line 8. The collector of the transistor Tr1 is connected through the resistor R3 to the output line 6 of the rectifying and smoothing circuit 1. The capacitor C7 is a means for countering noise.

The base of the transistor Tr2 is connected to the collector of the transistor Tr1. The emitter of the transistor Tr2 is connected to the common line 8. The

collector of the transistor Tr2 is connected through the resistor R4 to the base of the switching transistor Tr4. The emitter of the transistor Tr4 is connected to the output line 6 of the rectifying and smoothing circuit 1. The collector of the transistor Tr4 is connected to the main smoothing capacitor C2.

The secondary winding of the power transformer T includes a tap L deriving a predetermined voltage. The tap L is connected through the line 9 to the anode of the rectifying diode D5. The cathode of the diode D5 is connected through the line 5 to the output line 7 of the main smoothing capacitor C2. The tap L of the secondary winding of the power transformer T need not be exactly at mid point. The location of the tap L is selected in view of the design of the power transformer and the effect of the constant-voltage regulator 4. The secondary winding of the power transformer T may be divided into two windings.

The output line 7 of the main smoothing capacitor C2 is connected to the constant-voltage regulator 4. The constant-voltage regulator 4 is a circuit regulating the output voltage V_{OUT} to a fixed value of voltage. This circuit does not require a special form. The constant-voltage regulator 4 according to the present embodiment is usual and well known to a person concerned with the art. The constant-voltage regulator 4 is so made up that the zener diode D6, capacitor C3 and resistor R7 together produce the base voltage +Vs for controlling the output

voltage. The transistor Tr3 effectively compares the base voltage +Vs and the output voltage V_{OUT}, so that the output-control transistor Tr5 carries out a constant-voltage control of the output voltage V_{OUT}. The resulting output of the transistor Tr5 is applied through the capacitor C4 to the external output terminals OUT and COM which deliver electric power to external loads.

The operation of the present embodiment will be described hereinafter. The power supply can handle various levels of primary or input a.c. voltages and 100V- and 200-sources are chosen as examples of the input voltage.

(1) Case of the 100V-source primary or input voltage:

Fig. 2(a) and Fig. 2(b) are waveform diagrams illustrating an operation of the case of the 100V-source drives the primary or input side of the direct current power supply. The solid-lined voltage waveform of an alternating current appearing across the terminals HG (hereinafter, the arrow lying above letters indicates the direction of voltage vector) of the secondary winding of the power transformer is indicated at 10. The broken-lined voltage waveform of an alternating current appearing across the terminals $\overleftarrow{HL}$ or $\overleftarrow{LG}$ of the secondary winding is indicated at 11. The axis of time is indicated at 12. The ordinate representing a voltage level is indicated at 13. The output voltage (+Va) of the rectifying and smoothing circuit 1 is indicated at 14.

As understood from Figs. 1 and 2(a), (b), the voltage

10 across the terminals H and G of the secondary winding produces the smoothed output voltage 14 (+Va) through the rectifying and smoothing circuit 1 of Fig. 1. The resulting direct current output voltage 14 is divided by the resistors R1 and R2 of Fig. 1 to produce the direct current voltage +Vd. When the input voltage is 100V- the values of the resistors R1 and R2 are selected so that the level of the direct current voltage +Vd with its ripples will not exceed the voltage drop (V_{BE}) between the base and the emitter of the transistor Tr1 (i.e., $+Vd \leqq V_{BE}$). Base current cannot almost pass between the base and emitter of the transistor Tr1. The transistor Tr1 is off. Since the transistor Tr1 is off, base current passes through the resistor R3 from the output line 6 to the transistor Tr2 and the transistor Tr2 is on. When the transistor Tr2 is on, base current passes through the resistor R4 and the transistor Tr2 from the output line 6 to the switching transistor Tr4. The switching transistor Tr4 is on. Thus, when the input voltage is from the 100V- source, the output voltage +Va of the rectifying and smoothing circuit 1 charges the smoothing capacitor C2 at the voltage +Vc, reducing a corresponding voltage drop of the saturation voltage V_{CE} of the transistor Tr4. Since, normally, the saturation voltage V_{CE} of a transistor is sufficiently lower than the output voltage +V1, the equation $+Va \approxeq +Vc$ is established. That is, the charging voltage +Vc of the smoothing capacitor C2 may be considered equal to the output voltage +Va of the

rectifying and smoothing circuit 1. In the above-described state, the terminal voltages $\overleftarrow{HL}$ and $\overleftarrow{LH}$ between the tap L and terminal H of the secondary winding of the power transformer T is about 1/2 of the voltage 10 between the terminals H and G of the secondary winding as indicated by the broken-lined waveform 11 of Fig. 2. According to a charging loop made up of the tap L of the secondary winding and diodes D5, D1 and D2 (see also Fig. 5), the diode 5 is continuously reversedly biased with the charging voltage +Vc of the main smoothing capacitor C2. Thus, the charging loop does not operate.

Finally, in the case of the 100V-source primary or input voltage, the equivalent of the circuit of this invention is shown by Fig. 3, Fig. 3 briefly illustrates the voltage detector 3 and the constant-voltage regulator 4 but omits the diode D5. The circuit of Fig. 3, as well known, constitutes a single-phase bridge rectifier.

(2) Case of the 200V-source primary or input voltage:

Fig. 4(a) and Fig. 4(b) are waveform diagrams illustrating the operation of the case of the 200V-source primary or input voltage of the direct current power supply. The solid-lined voltage waveform of an alternating current appearing across the terminals $\overleftarrow{HG}$ of the secondary winding of the power transformer is indicated at 20. The solid-lined voltage waveform of an alternating current appearing across the terminals $\overleftarrow{HL}$ or $\overleftarrow{LG}$ of the secondary winding is indicated at 21. The output voltage of the rectifying and smoothing circuit 1

is indicated at 22. The charging voltage waveform of the main smoothing capacitor C2 is indicated at 23. The ordinate representing a voltage level is indicated at 25. The peak value of the waveform 21 is indicated at <u>a</u>. The peak value of the waveform 20 is indicated at 2a.

Figs. 4(a), (b) are similar to Figs. 2(a), (b) illustrating the 100V-source. The level of the waveform of Fig. 4(a) is about twice that of Fig. 2(a).

As understood from Figs. 1(a), (b) and 4(a), (b), the voltage 20 across the secondary winding produces the direct current voltage 22 through the rectifying and smoothing circuit 1 of Fig. 1. The resulting direct current output voltage 22 is divided by the resistors R1 and R2 to produce the direct current voltage +Vd. When the input voltage is 200V- the values of the resistors R1 and R2 are selected so that the level of the direct current voltage +Vd with its ripples will exceed the voltage drop (V_{BE}) between the base and emitter of the transistor Tr1 in order to pass base current. Thus, the transistor Tr1 is continuously on.

The values of the resistors R1 and R2 are selected relative to the voltage V_{BE} between the base and emitter of the transistor Tr1 so that base current is interrupted in the case of the 100V-source input and so that enough base current is established in the case of the 200V-source input.

When the transistor Tr1 is on, the subsequent transistor Tr2 is off since corresponding base current

fails to pass. The switching transistor Tr4 is also off. The output voltage of the rectifying and smoothing circuit 1 fails to charge the main smoothing capacitor C2 but only charges the auxiliary voltage-detecting and smoothing capacitor C1 at the direct current voltage +Va for a voltage-detecting signal. In this state, the discharge current from the auxiliary smoothing capacitor C1 is low and includes less ripples as shown by the waveform 22 of Fig. 4(b) than the discharge current as shown by the waveform 14 of Fig. 2(b) since the switching transistor Tr4 is off.

Since the voltage detector 3 fails to serve to charge the main smoothing capacitor C2, the voltage detector 3 and voltage-constant regulator 4 are simplified as shown by Fig. 5(a) for a better understanding of the charging system. Fig. 5(b) illustrates the main part of the circuit of Fig. 5(a) for a further better understanding of the charging system. The circuit of Fig. 5(b) is equivalent to so-called center-tap-type single-phase full-wave rectifier.

Figs. 6 and 7 illustrate directions of current flows in the charging loop.

Fig. 6 illustrates a case in which the order of induced voltages by the secondary winding is expressed as H > L > G. In this case, the terminals L and G of the secondary winding and the diodes D2 and D5 together serve to charge the main smoothing capacitor C2. When the order of induced voltages by the secondary winding is expressed

as H < L < G, the terminals L and H of the secondary winding and the diodes D1 and D5 together serve to charge the main smoothing capacitor C2, as shown in Fig. 7.

Thus, the winding across the termianls H and L or terminals L and G of the secondary winding of the power transformer alternately charges the main smoothing capacitor C2. The voltages induced across the terminals H and L and terminals L and G are a 1/2 induced voltage across the terminals H and G. The waveform of a charging voltage of the main smoothing capacitor C2 is shown by the charging-voltage waveform 23 of Fig. 4(b) which corresponds to the waveform 14 of Fig. 2(b) illustrating the 100V-source input case.

According to the embodiment of this invention, the charging voltages of the main smoothing capacitor C2 are substantially equal regardless of the input voltage. A final constant-voltage output is produced by the ordinary constant-voltage regulator 4 connected to the main smoothing capacitor C2.

Although only one embodiment of this invention has been described, the invention can be realized in other ways.

CLAIMS

1. A direct current power supply for converting alternating current into direct current comprising: a power transformer having a primary winding connectible to a source of alternating current and a secondary winding with a plurality of outputs; a plurality of rectifying means connected to the outputs of the transformer; detecting means for detecting a predetermined level of alternating current voltage; and switching means for connecting and disconnecting the rectifying means under control of the detecting means; whereby an appropriate rectifying circuit is selected from the rectifying means in response to a variation of the amplitude of the alternating current voltage to prevent variation in output voltage.

2. A power supply according to claim 1, wherein one of the outputs of the secondary winding of the power transformer and a group of rectifying means connected to the output collectively form a single-phase bridge rectifying circuit which is operative when the input alternating current voltage is low and another ot the outputs of the secondary winding of the power transformer and a group of rectifying means connected to the ouput collectively form a single-phase full-wave-rectifying circuit which is operative when the input alternating current voltage is high.

3. A power supply according to claim 2, wherein said one output terminals of the secondary winding of the power

transformer is connected to the alternating-current input of the single-phase bridge rectifying current and a direct current output of the single-phase bridge rectifying circuit is connected to the detecting means via a first smoothing capacitor and is connected to a second smoothing capacitor via the switching means.

4. A power supply according to claim 3, wherein the secondary winding of the power transformer has a tap connected to the second smoothing capacitor via one of the rectifying means.

5. A power supply according to any one of claims 1 to 4, wherein a constant-voltage regulator and stabilizing circuit is connected to the rectifying circuit.

6. A direct current power supply comprising a power transformer having a primary winding with input terminals for connection to a source of alternating current and a secondary winding with output terminals, a plurality of rectifying circuits connected to the output terminals and means for automatically selecting an appropriate rectifying circuit in dependence on the voltage applied to the input terminals.

7. A power supply substantially as described with reference to, and as illustrated in, Figure 1 of the accompanying drawings.

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